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Status of Lake Michigan Salmonines in 2008

Report from the Salmonid Working Group
to the Lake Michigan Committee



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Introduction

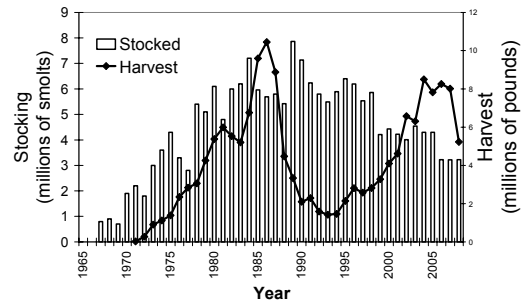
The overall fisheries management goal established for Lake Michigan in the Fish-community Objectives (FCO) is to restore and maintain the biological integrity of the fish community so that production of desirable fish is sustainable and ecologically efficient (Eshenroder et al. 1995). The salmonine objective specifies establishment of a diverse salmonine community capable of sustaining an annual harvest of 2.7 to 6.8 million kg, of which 20-25% is lake trout *Salvelinus namaycush*.

Inherent in this objective is the desire to maintain a salmonine community that has abundant levels of Chinook salmon *Oncorhynchus tshawytscha* (i.e., target annual yield of 3.1 million kg) sufficient to suppress alewife *Alosa pseudoharengus* populations but not beyond levels where predator consumption would threaten food web integrity. The Salmonine and Planktivore Objectives are based on the understanding that large populations of exotic forage fishes, such as alewife and rainbow smelt *Osmerus mordax*, negatively impact recruitment of native fishes, and that controlling exotic prey fishes presents an opportunity to create new, diverse fishing opportunities. Therefore, progress toward these objectives is evaluated by determining the relative balance between predator and prey (e.g., Chinook salmon and alewife interactions) rather than suppression of alewife through extreme top-down predation.

Chinook salmon stocking levels were highly correlated with harvest in the first two decades of stocking. There was a disparity between stocking and harvest,

even with sustained stocking rates, during the late-1980s.

Figure 1. Chinook salmon stocking and harvest



Chinook salmon experienced a noticeable disease epizootic and a significant decline in abundance in 1987-88. It was not until 1999 that a coordinated Chinook salmon stocking reduction was implemented in hopes of minimizing risk to the fishery associated with instability in Chinook salmon survival (Figure 1). Since 1985, it is apparent that trends in harvest are no longer related to stocking alone (Figure 1).

Through the Lake Michigan Technical Committee process, a Salmonid Working Group (SWG) was established to evaluate the effects of the stocking reduction and to identify indicators useful in the early detection of future Chinook salmon population stress; these indicators were originally referred to as the “10 Red Flags”. Further imbalance in predator-prey levels necessitated another Chinook salmon stocking reduction in 2006.

The purpose of the SWG is to cooperatively collect and disseminate knowledge regarding Lake Michigan salmonines and to assess the status of pelagic salmonines and their prey (Terms of Reference for the Salmonid

Working Group 2008). The SWG's main goal is to evaluate progress toward achieving the Salmonine FCO aimed at maintaining a diverse salmonine community. Currently, the SWG implements and continues to develop a science-based approach (i.e., Red Flags) for annually evaluating measurable indices of the salmonine and planktivore populations, and recommends changes in management, if necessary, based on the results of the Red Flags analysis. This evaluation, along with consultation with managers and constituents, has resulted in two (1999 and 2006; Figure 1) lakewide stocking reductions of approximately 25% of the Chinook salmon stocked into Lake Michigan.

Methods

The SWG uses a set of criteria to measure the health of the Chinook salmon population and identify potential threats to predator-prey populations. The biological criteria utilize all currently available data from ongoing assessments, including: estimates of **abundance** from creel and fishery-independent surveys, stocking records and estimates of **natural reproduction**, estimates of salmonine size-at-age and **growth**, trends in **prey fish abundance**, and indices of fish **health** and system **integrity**. For each biological category, we have several indices available for analysis. However, we have selected only a few representative parameters from each category to present here.

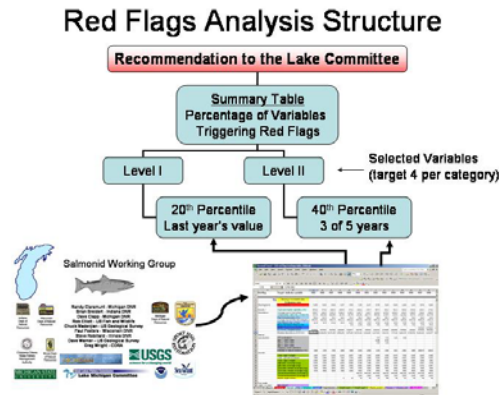
In 2008, MDNR discontinued their fishery-independent (gill net) survey of salmonines in Lake Michigan resulting in the loss of several parameters including relative abundance, clip ratio, weight-at-age of young fish, diet / ration,

disease prevalence, and lipid content / fat reserves from percent water measures. The Red Flags analysis for 2008, therefore, incorporates many new indicators (e.g., Michigan's weir returns as another index of abundance) to replace indices no longer collected in the MDNR survey. In addition, we have included indicators for the other salmonines including trends in coho size and composition of the harvest, and we hope to include data on lake trout as well in future years.

Similar to the results from previous years, we used the frequency distributions of the selected variables to indicate when values for the current year (Level I) or three of the previous five years (Level II) are outside an acceptable range. Evaluated parameters indicate imbalance (i.e., trigger red flag) when:

- **Level I:** A value from the most recent year of data that is lower than the 20th or higher than the 80th percentile will trigger a red flag.
- **Level II:** Values from three out of the last five years which are lower than the 40th or higher than the 60th percentile will trigger a red flag.

If more than 50% of the variables for either level indicate red flags, the SWG will make a recommendation to the Lake Michigan Committee to consider revising management actions (e.g., stocking rates or fishery regulations) for salmonines in Lake Michigan.



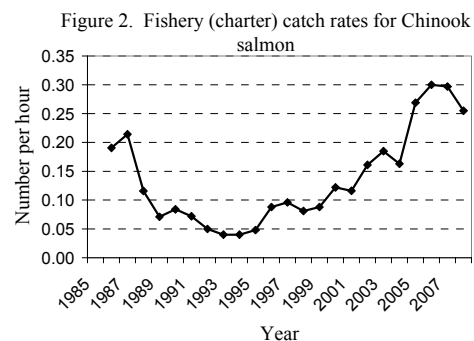
The data included in this report are provided by several agency and university sources (see diagram above). Members of the SWG assist in the collection and/or consolidation of such data by providing summary statistics in a lakewide time-series table. The data in the table cover 1985-present and are used herein to evaluate the overall predator-prey balance necessary to achieve the Lake Michigan Salmonine Objective.

Results and Discussion

Abundance: Total lakewide harvest, charter fishery catch rates, Illinois DNR electrofishing survey CPEs, and Michigan's weir returns were utilized to evaluate trends in Chinook salmon abundance in 2008. Chinook salmon are used as the indicator of overall predator abundance because of the availability of data and because of the demand placed on the prey population due to their high consumption rate. Lakewide harvest of Chinook salmon was highest in the late 1980s, declined substantially during 1989-1994, increased steadily since 1995, but dropped substantially in 2008 (Figure 1). The estimated harvest for 2008 was approximately 2.37 million kilograms (kg), which is a large decrease from 3.6 million kg in 2007, but still above the long-term average. Annual

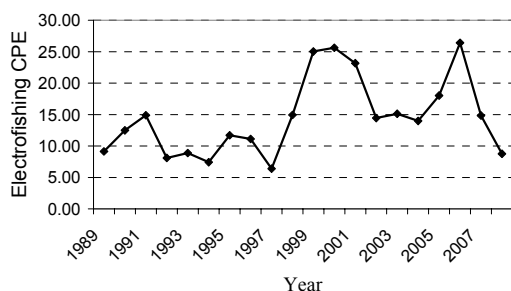
lakewide harvest has ranged from 0.6-4.7 million kg with a long-term average (\pm SE) harvest of 1.94 ± 0.3 million kg (Table 1).

Similarly, catch rates in the recreational fishery, using Michigan charter CPE as an index, declined in the late 1980s, were low during 1992-1994, but have been rising since 1995 until 2008 (Figure 2). In 2008, estimates of catch rate declined from approximately 30.0 to 25.5 fish per 100 hours. Average catch rate over the entire time series is 13.7 ± 1.7 and ranged from 4.0 – 30.0 fish per 100 hours of fishing (Table 1). Even though catch rates declined in 2008, they were still above the long-term average. Previous SWG reports predicted the observed decline because recreational catch rates had been at all-time high levels during 2006-2007 (30 fish and 16.0 fish per 100 hours for the charter and non-charter fisheries, respectively; Claramunt et al. 2008).



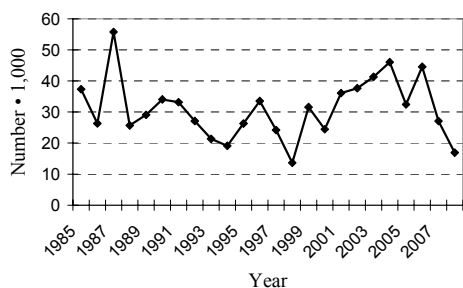
Illinois DNR electrofishing survey CPEs (Chinook salmon / hr) increased from 1997 to 2000, decreased during 2001 to 2004, but increased again in 2005 and 2006 (Figure 3). Since 2006, however, survey CPE has been decreasing and was 8.8 fish per hr of electrofishing in 2008. CPE is currently below the average of 14.5 (Table 1).

Figure 3. Illinois Harbor Survey



The decrease in electrofishing survey CPE is similar to sharp declines seen in returns to Michigan's weirs (Figure 4). Weir returns dropped to 16,907 fish; the second lowest return in the time series. The drop in returning Chinook salmon may be due to lower survival of age 2 and 3 year old fish from the decline in adult alewife biomass.

Figure 4. Michigan Weir Returns



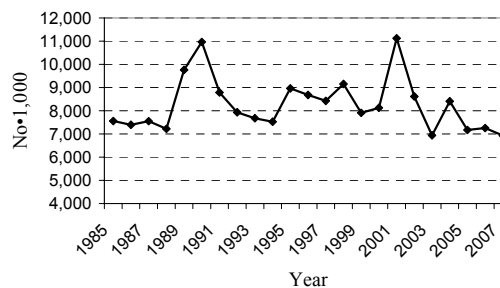
With the exception of the level I indicator for total harvest, all of the abundance indicators triggered both level I and II red flags (Table 1).

Reproduction: Recruitment of naturally-produced Chinook salmon smolts has increased since their introduction in 1967. Natural reproduction has been estimated periodically throughout the period 1985-2008. Estimates in the early 1990s from oxytetracycline (OTC) studies suggested that natural recruitment accounted for 29-35% of lakewide adult stocks when

stocking levels were near their highest (6-7 million smolts; Figure 1 and 5).

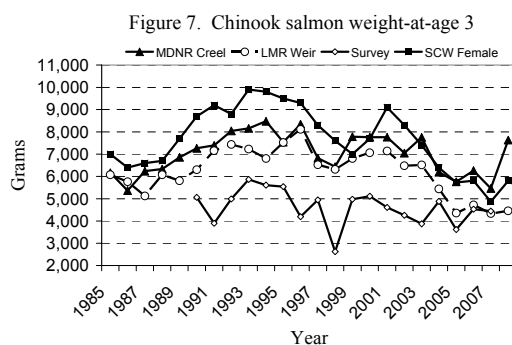
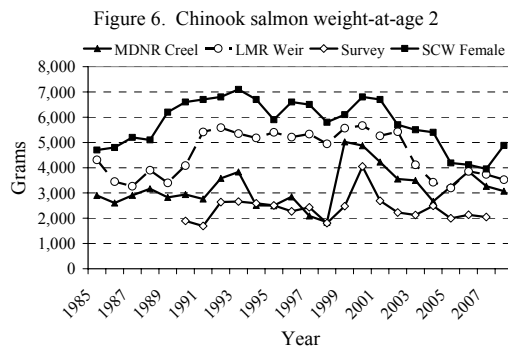
Estimates for 2001-2003 from OTC-marked fish collected in 2004 and, more recently, estimates from the lakewide OTC evaluation starting with the 2006 year-class (Claramunt et al. 2007), indicate that natural recruitment has increased such that natural recruits now account for over 50% of the lake population (Table 1), which is higher than the estimated average of 43.2%. In 2008, the percent of wild Chinook salmon dropped from 54 to 52.8 % and estimated total recruitment (natural and hatchery recruitment combined) has declined to 6.8 million smolts. The decline in Chinook salmon recruitment is, in part, due to stocking reductions aimed at reducing total Chinook salmon abundance to be more in alignment with prey abundance (Figure 5). Because the total number of Chinook salmon recruits entering the lake is at all-time lows (since 1985), and contribution from wild production has been declining, the variables for natural reproduction triggered level I and II red flags with the exception of percent OTC marked for level I (Table 1).

Figure 5. Total Chinook salmon recruitment



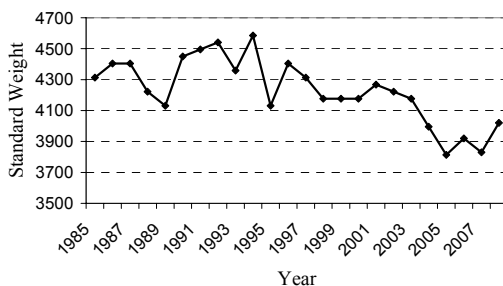
Growth: Several weight-at-age indices suggest that growth conditions have changed over time, presumably from changes in Chinook salmon abundance,

forage levels, and environmental factors (Figures 6 and 7).



For this report, we selected Chinook salmon weight-at-age 2 and 3 from the MDNR creel survey (male and female combined), weight-at-age 3 (females only) from Strawberry Creek (WI) weir returns (Figures 6 and 7), and the standard weight index (again from the Strawberry Creek weir; Figure 8) to assess changes in growth (Table 1).

Figure 8. Standard Weight



Most of the data sources indicate that weight-at-age peaked in 2000-2001, following the production of an abundant year-class of alewife in 1998, and declined from 2002 through 2007. In

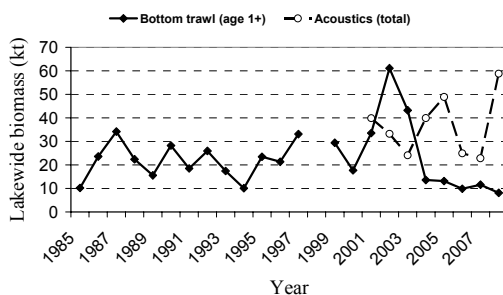
2008, however, creel survey weight-at-age decreased for age-2 to 3,070 grams (g). Average weight-at-age 2 from the creel was $3,190 \pm 158$ g and ranged from 1,842-5,021 g throughout the time series (Figure 6; Table 1). In 2008, weight of age-3 Chinook salmon increased at the Strawberry Creek weir (5,800 g) and from creel samples (7,634 g) from 2007 levels. With respect to the long term averages, weight-at-age 3 was lower for the weir (average $7,650 \pm 295$ g) and higher for the creel (average $7,037 \pm 188$ g). Also, the standard weight index in 2008 (4,020 g) increased from 2007, which was near the lowest for the time series (average standard weight $4,230 \pm 43$ g). Weight-at-age indicators improved in 2008 so that only weir weight-at-age 3 triggered a level I red flag. However, all four growth indicators triggered red flags for level II (Table 1).

Prey fish abundance: Estimates of forage fish biomass are reported in kilotonnes (kt; 1 kt = 1,000 metric tons) of age-1 and older alewife from bottom trawl surveys and in kt of total alewife biomass from acoustic surveys (Figure 9). Average biomass from bottom trawl surveys is 22.8 ± 2.6 kt, ranging from 8.1-61.1 kt during 1985-2008 (Table 1; Bunnell et al. 2009). In 2008, alewife biomass from the bottom trawl was the lowest value (8.1 kt) in the time series (1985-2008; Table 1). In contrast, alewife biomass estimated from acoustic surveys was the highest value (58.8 kt) in the time series (2001 – 2008; Figure 9). Alewife biomass from 2001 -2008 acoustic surveys averaged 36.6 ± 4.6 kt and ranged from 22.3-58.8 kt (Table 1). Even though the acoustic estimate of alewife biomass was high in 2008, it was below values from the 1990 acoustic

survey (Warner et al. 2008; Warner et al. 2009) and below the recommended level in the Planktivore FCO.

Because alewives are not fully recruited to the bottom trawl until age 3, these data suggest that the abundance of large, old alewives are at all time lows. The acoustic survey, however, is very efficient at sampling younger ages of alewives (ages 0-2). These results indicate that the abundance of young alewives is very high. Warner et al. (2009) conclude that contribution of older alewife in 2008 was low; the 2001-2004 year-classes comprised only 16.0% of the alewife population. Therefore, both bottom trawl and acoustic estimates of alewife biomass triggered level I and level II red flags in 2008.

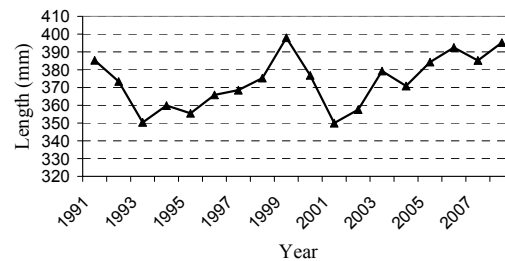
Figure 9. Lakewide alewife biomass



In previous reports, we used alewife abundance in predator diets as another indicator of changes in prey abundance. Unfortunately, predator diet samples (grams of total prey in stomach) are no longer available (see Methods section). As a replacement for an index of diet conditions, we used the average length of a jack coho salmon returning to Michigan weirs because their growth represents prey availability in one growing season only. Changes in the length of a coho jack should be closely related to changes in alewife abundance, or at least juvenile alewife abundance. Similar to previously reported results for

trends in Chinook salmon diets/ration, coho lengths were low in the mid 1990s, peaked following the strong 1998 year-class of alewife, declined, but then recovered following increases in young-of-year production of alewives starting with the 2002 year class (Figure 10).

Figure 10. Mean length of a coho jack returning to Michigan's weirs

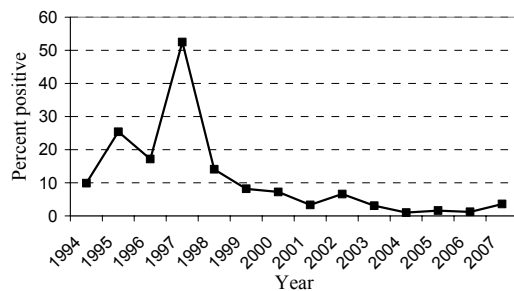


Average length of a coho jack for 1991-2008 was 374 ± 3.5 mm and ranged from 350 to 398 mm (Table 1). In 2008, the average length of a coho jack continued a several year trend of increasing length and was extremely high (395 mm), suggesting that an abundance of small prey exists in Lake Michigan in 2008. However, both level I and II red flags were triggered because the values were outside of the acceptable range (Table 1).

Fish health: Fish health has been monitored using several tests (e.g., visual signs, FELISA, QELISA, DFAT) for the presence of *Renibacterium salmoninarum*, the causative agent for bacterial kidney disease (BKD). Stress-mediated diseases such as BKD can have strong regulatory influences on Chinook salmon populations. Additionally, using consistent methods, gross clinical (visual) signs of disease have been recorded for fish captured in the open-water survey and for weir returns. Critical information from the fishery-independent survey is no longer

available. Less than 0.5% of the weir-returning Chinook salmon showed any sign of disease in 2008, and no red flags were triggered (Figure 11; Table 1).

Figure 11. Visual signs of disease from weirs

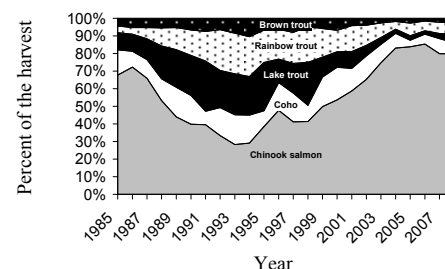


Percent water in the body muscle has been used to evaluate changes in fat reserves, another indicator of Chinook salmon health. Laboratory and field studies have been used to establish a level of $\leq 78\%$ water in the muscle as an indicator of insufficient fat reserves. Percent water results from 2001-2007 suggested that Chinook salmon in Lake Michigan may have entered into a period with very low energy reserves. Unfortunately, percent water values were not collected in 2008 and will likely not be used as a future red flags indicator.

System Integrity: In 2008, the SWG was asked by the Lake Michigan Committee to incorporate additional indicators for other salmonines such as brown trout, coho salmon, steelhead, and lake trout. With the additional indicators, the red flags analysis could be expanded to evaluate the objective to maintain biodiversity in the predator-prey complex with the view of promoting ecosystem integrity. In response to the LMC request, we used the proportion of the harvest that was comprised of the other (not Chinook salmon) salmonines and evaluated the

trend using the red flags approach. The recommended composition in the Salmonine Objective (interpreted from the recommendations for total harvest by salmonine) is 50% Chinook salmon and 20-25% lake trout. The average percent of the harvest that is comprised of salmonines other than Chinook salmon is $43.5 \pm 3.8\%$ (Table 1). However, the percent composition was low in 2008 (20.2%) and has been low for several years (Figure 12). This is likely directly related to above-average catch rates for Chinook salmon rather than unusually low abundance of the other species. However, the percent composition of the harvest for the other salmonines triggered a level II red flag.

Figure 12. Composition of the lakewide harvest



Summary

Chinook salmon stocking rates were adjusted in 1999 and 2006, through a cooperative process, in an attempt to minimize the risk of a lakewide salmon population crash and its effects on the fishery. These stocking reductions were based on a review of biological indicators from the SWG and reflected the consensus of fisheries managers from each agency. To assist in this management process, the SWG is committed to including new indicators (e.g., the addition of coho trends) and continuing the ongoing collection and consolidation of lakewide time series data on salmonines in Lake Michigan. In response to the request from the

LMC, the SWG would like to incorporate additional trends for lake trout (e.g., trends in lakewide egg thiamine levels, abundance, growth, and age structure) for the health and integrity section of the Red Flag analysis.

Chinook salmon harvest in 2004-2007 was above the established reference level set forth in the Salmonine Objective for Lake Michigan (3.1 million kg / 6.8 million pounds; Figure 1), but dropped substantially to within the Salmonine Objective range in 2008. This observation was expected based on our analysis of the 2007 Red Flag parameters, from which the SWG concluded that the previous harvest levels were not sustainable and declines in fishery catch rates and harvest levels in the near future were inevitable. Indicators of salmon abundance suggested that there was a decline in 2008, and the frequency distributions of many of the selected parameters were outside of the acceptable ranges; 53% (8 of 15) of the variables triggered level I red flags and 93% (14 of 15) of the variables triggered level II red flags. However, the directions of these triggers were mixed, falling both above and below acceptable ranges.

Recommendations

Our evaluation suggests that we are likely not meeting all of the Salmonine Objectives. Because over 50% of the level I and II red flag indicators were triggered in 2008, **the SWG recommends that the Lake Michigan Committee (LMC) carefully review salmonine management objectives, strategies, and options to bring a better balance between predator and prey in Lake Michigan.**

Although many of the predator-prey indicators were outside of acceptable ranges, the LMC should be aware that the “flags” are not all pointing in the same direction. For example, weight-at-age indicators improved in the last year (i.e., level I), but have been trending low for several years (i.e., level II). Moreover, indicators of Chinook salmon abundance declined substantially in 2008 (e.g., harvest, survey, and weir returns), but the proportion of the other salmonines in the harvest did not improve as much as expected. Lastly, alewife biomass was estimated to be at a record low based on the bottom trawl survey and a record high based on the acoustic survey. These conflicting results suggest that large scale changes in the predator-prey relationship are underway; in part from the recent stocking reduction, but probably also as a result of conditions independent of management actions.

The SWG understands that salmonine stocking policies are typically reviewed periodically (4 to 6 years); however, managers may want to consider a full review of salmonine stocking in the near future, or at least a review of the potential changes that could occur in the years ahead. The 2007 Red Flag analysis indicated that the predator abundance (as indicated by Chinook salmon) was too high and likely not sustainable (Claramunt et al. 2008). One minor change in the fishing regulations that will be implemented in 2009 is the increase in the Chinook and coho salmon daily bag limit from 3 to 5 fish in Michigan waters; this will likely have a minor impact on harvest (Claramunt et al. In press).

In addition to the indicators of Chinook salmon abundance (e.g., harvest and weir returns), the 2008 bottom trawl survey indicates that the biomass of large alewife has declined substantially (Bunnell et al. 2009). Either through a decrease in density-dependent influences or as a result of the decline in Chinook salmon abundance, the recruitment and survival of young alewife appeared to be above expectations. In addition to the acoustic estimates of alewife biomass (comprised mainly of young age classes), the new index of the length of a jack coho salmon seems to support the measured increase in small alewives. If these young alewife experience good survival, they may produce an abundance of adult alewife greater than is desired for achieving other FCOs.

Fishery managers may want to pay special attention to predator-prey levels in 2009, as the system appears to be unstable. Additional indicators for lake trout and other species will help provide insights into the state of the Lake Michigan food web. However, the loss of valuable indicators (e.g., predator diet information, percent water index of condition) will impede the SWG's ability to fully assess the status of predator-prey levels relative to management objectives.

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Table 1. Selected red flag variables; data in this summary table were collected during the period 1985-2008.

Biological Variable	Min	Max	Mean	SE	2008	Current Year		Three Out of Five Years	
						Level I	Level I	Level II	Level II
						Values	Acceptable Range	Red Flag¹	Acceptable Range
Abundance									
Harvest (kg x 1 million)	0.64	4.74	1.94	0.3	2.37	0.97 – 3.90	No	1.49 – 2.37	Yes
Charter CPE (n per 100 hrs)	4.0	30.0	13.7	1.7	25.5	6.68 – 22.2	Yes*	8.8 – 13.8	Yes*
Survey (electrofishing n per hr)	6.39	26.4	14.5	1.4	8.76	8.8 – 22.1	Yes*	12.0 – 14.9	Yes*
MI weir returns (n x 1000)	13.6	55.8	31.0	2.0	16.9	24.2 – 37.6	Yes*	27.1 – 33.1	Yes
Natural Reproduction									
Percent unmarked (OTC)	23.0	65.8	43.2	4.0	52.8	31.6 – 53.6	No	41.3 – 49.0	Yes
Total Recruits (n x 1 million)	6.8	11.1	8.2	0.2	6.8	7.2 – 9.0	Yes	7.6 – 8.4	Yes
Growth Indices									
Creel weight-at-age 2 (g)	1,842	5,021	3,190	158	3,070	2,601 – 3,832	No	2,900 – 3,252	Yes
Creel weight-at-age 3 (g)	5,367	8,479	7,037	188	7,634	6,192 – 7,786	No	6,825 – 7,538	Yes
Weir weight-at-age 3 (g)	4,870	9,900	7,650	295	5,800	6,390 – 9,200	Yes	6,671 – 8,300	Yes
Standard weight (g)	3,814	4,585	4,230	43	4,020	4,020 – 4,313	No*	4,177 – 4,313	Yes
Prey fish Abundance									
Acoustic biomass (kt)	22.3	58.8	36.6	4.6	58.8	23.8 – 50.9	Yes	29.9 – 39.9	Yes
Bottom trawl (kt)	8.1	61.1	22.8	2.6	8.1	11.3 – 33.2	Yes	17.6 – 23.5	Yes
Length of coho jacks (mm)	350	398	374	3.5	395	357 – 387	Yes*	370 – 378	Yes*
Health and Integrity									
Other² salmonine harvest (%)	14.6	71.7	43.5	3.8	20.2	20.2 – 60.5	No*	34.8 – 52.3	Yes
Visual Signs - Weir (%w/o)	87.6	99.5	95.1	0.6	99.5	92.6 – 100	No	94.8 – 100	No

¹Yes = data outside of acceptable range. ² = Other than Chinook salmon.

* =A change in the Red Flag from the previous survey year (2007).